PATENT ABSTRACTS OF JAPAN

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(54) COMPLEX BAND-PASS FILTER

(57)Abstract:
PROBLEM TO BE SOLVED: To improve the distortion of a signal in a filer passing band due to frequency characteristics of an operational transconductance amplifier.
SOLUTION: A complex band-pass filter which has 1st to 6th OTA21 to OTA26 and 1st and 2nd capacitors 27 and 28 is provided with a 1st resistance 29 (or transistor) which has a resistance value Ra for canceling the distortion of an in-phase component signalin the passing band between the 1st capacitor 27 on the output side of the first OTA21 and the earthand with a 2nd resistance 30 which has a resistance value Rb for canceling the distortion of an orthogonal component signal in the passing band between the 2nd capacitor 28 on the output side of the second OTA22 and the ground. Those resistance values Ra and Rb are set with $2/(\omega bC)$. Consequentlythe signals in the passing band have no distortion.

CLAIMS

[Claim(s)]
[Claim 1]The 1st transconductance element which inputs an in-phase component signal of quadrature modulationand defines an output gain of this in-phase component signal.
The 1st capacitor for being connected between an output terminal of this 1st transconductance elementand a groundand defining pass band width of an in-phase component signal.
An in-phase component output side element which inputs an output of the above-mentioned 1st transconductance elementand defines pass band width of an in-phase component signal with combination with the 1st capacitor of the aboveThe 2nd transconductance element which receives a quadrature component signal of quadrature modulation and defines an output gain of this quadrature component

signalThe 2nd capacitor for being connected between an output terminal of this 2nd transconductance elementand a groundand defining pass band width of a quadrature component signalA quadrature component output side element which inputs an output of the above-mentioned 2nd transconductance elementand defines pass band width of a quadrature component signal with combination with the 2nd capacitor of the aboveAn element for frequency shifts for being connected between a node of the above-mentioned 1st transconductance element and an in-phase component output side elementthe above-mentioned 2nd transconductance elementand a node of a quadrature component output sideand shifting center frequency of a pass band.
Are the complex band pass filter provided with the aboveand it is connected between an output terminal of the above-mentioned 1st transconductance elementand a groundThe 1st resistance generating element which generates resistance for negating distortion of a pass band of an in-phase component signal generated with the limited frequency characteristic of this 1st transconductance element and the above-mentioned element for frequency shiftsIt is connected between an output terminal of the above-mentioned 2nd transconductance elementand a groundThe 2nd resistance generating element which generates resistance for negating distortion of a pass band of a quadrature component signal generated with the limited frequency characteristic of this 2nd transconductance element and the above-mentioned element for frequency shifts was provided.

[Claim 2]A complex band pass filter given in above-mentioned claim 1 characterized by using a resistance element as the above 1st and 2nd resistance generating element.
[Claim 3]A complex band pass filter given in above-mentioned claim 1 using a transistor element which operates in a triode field as the above 1st and 2nd resistance generating element.
[Claim 4]The limited frequency characteristic of the above-mentioned 1st transconductance element and an element for frequency shifts and a value of the 1st capacitor of the above determine resistance of the above-mentioned 1st resistance generating elementA complex band pass filter given in above-mentioned claims 1 thru/or 3 determining resistance of a resistance generating element of the above 2nd with the limited frequency characteristic of the above-mentioned 2nd transconductance element and an element for frequency shiftsand a value of the 2nd capacitor of the above.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to a complex band pass filter and the complex band pass filter for being used for a phase convertera Hilbert

transformation machineetc. 90 degreesand oppressing an image signal especially.
[0002]
[Description of the Prior Art]In recent yearsthe Low-IF method which sets an intermediate frequency (IF) as several MHz or less attracts attention with the spread of walkie-talkie terminals instead of the superheterodyne system which is the conventional receiving method. If this Low-IF method is adoptedthe external IF filter with a big outside dimension which was needed with the above-mentioned superheterodyne system can be removedand one-chip-izing and the advantage that the price can fall will be acquired in a receive section.
[0003]Howeverin this Low-IF methodsince received frequency (RF) and the frequency of a local oscillator are nearoppression of an image signal becomes indispensableand a complex band pass filter exists as a means to oppress this image signal. There is a thing using operational research transconductance amplifier (referred to as OTA below) as a kind of this complex band pass filterand thisFor exampleIEICE TRANS.FUNDAMENTALSVol.E80-Aand No.9 monthSeptember1997It is indicated to the paper of Xiaoxing ZHANG carried on 1724 pages from 1721 pagesImplementation of Active Complex Filter with Variable Parameter Using OTAsetc.
[0004]The composition of the primary complex band pass filter described in the above-mentioned paper is shown in drawing 4.
In this filterinput signal X_R of the in-phase component of quadrature modulation is inputtedThe 1OTA1 with the transconductance of gm3a and the output side of this 1st OTA1 are connected3rd OTA3 with the transconductance of gm1a is providedand output signal Y_R of an in-phase component is outputted from this the 3OTA3.
On the other handinput signal X_I of the quadrature component of quadrature modulation is inputtedand the 2OTA2 with the transconductance of gm3b and the output side of this 2nd OTA2 are connected4th OTA4 with the transconductance of gm1b is providedand output signal Y_I of a quadrature component is outputted from this the 4OTA4.
[0005]In order to achieve a frequency shift function between the nodes B of the above-mentioned 1st OTA1the node A of 3rd OTA3 and the above-mentioned 2nd OTA2and 4th OTA4The 5OTA5 and 6th OTA6 are providedthis 5th OTA5 has a transconductance of gm2aand 6th OTA6 has a transconductance of gm2b.
Between the above-mentioned node A and a groundthe 1st capacitor 7 of capacity Ca is connected and the 2nd capacitor 8 of the capacity Cb is connected between the above-mentioned node B and a ground.
[0006]And transfer function H(s) [s of such primary complex band pass filter : complex variable]In the above-mentioned transconductanceit is gm1a=gm1b=gm1gm2 a=gm2b=gm2and gm3a=gm3b=gm3and when it is considered as Ca=Cb=Cit is given by a following formula.
[0007]
[Equation 1]

j is an imaginary unit and is $j^2=-1$.

[0008]According to such a complex band pass filterabout input signal X_R of an in-phase component. Are a gain determined by transconductance gm3aand output signal Y_R of the pass band width determined by capacity Ca and transconductance gm1a is obtainedAbout input signal X_I of a quadrature componentoutput signal Y_I of the pass band width which is a gain determined by transconductance gm3band is determined by the capacity Cb and transconductance gm1b is obtained. And frequency is shifted to those for Masakata only the quantity determined with the above-mentioned capacity Ca and Cband transconductance element gm2a and gm2b.

[0009]The frequency characteristic which took angular-frequency omega along the horizontal axis is shown in drawing 5.

According to the above-mentioned complex band pass filteronly $omega_c$ can shift center frequencyfor example from $-omega_0$ like the frequency characteristic 100 to the frequency characteristic 101 of the bandwidth of $+omega_0$and although it lets positive frequency pass by thisthe filter which does not let negative frequency pass is obtained.

And a high order complex band pass filter is formed by carrying out cascade connection of such a primary complex band pass filter.

[0010]The composition of the 4th Bata Wace type complex band pass filter is shown in drawing 6.

This shall be 2 MHz in center frequencyand shall be 1 MHz in pass band widthfor example.

The 1st filter 10 of a graphic display Namelygm1a=gm1b=29microS (siemens)It is set as gm2 a=gm2b=137.7microSgm3a=gm3b=59microSand a Ca=Cb=10pF valueand the 2nd following filter 11It is set as gm1a=gm1b=29microSgm2 a=gm2b=113.6microSgm3a=gm3b=59microSand a Ca=Cb=10pF valueand the 3rd filter 12It is set as gm1a=gm1b=12microSgm2 a=gm2b=154.7microSgm3a=gm3b=59microSand a Ca=Cb=10pF valueand the 4th filter 13 of a final stageIt is set as gm1a=gm1b=12microSgm2 a=gm2b=96.6microSgm3a=gm3b=59microSand a Ca=Cb=10pF value.

[0011]The ideal frequency characteristic of the 4th Bata Wace type complex band pass filter of drawing 6 is shown in drawing 7.

2 MHz is made into center frequency and the characteristic of the bandwidth which lets positive frequency pass is obtained so that it may be illustrated.

[0012]

[Problem(s) to be Solved by the Invention]Howeverthe frequency characteristic of the complex band pass filter of above-mentioned drawing 7It is when the frequency characteristic of the transconductance gm of each OTA (operational research transconductance amplifier) 1-6 is idealand there was a problem that a big distortion arose into the pass band portion of a signal actually.

[0013]When the frequency characteristic of the actual complex band pass filter is

shown in drawing 8and the frequency (cut off frequency) which falls by -3 dB by gm of this OTA is 20 MHzas it is shown in drawing 8A big distortion occurs in the pass band width (1 MHz) centering on the frequency of 2 MHz.
[0014]This invention is made in view of the above-mentioned problemand the purpose is to provide the complex band pass filter which can improve distortion of the signal of the filter pass band region resulting from the frequency characteristic of operational research transconductance amplifier good.
[0015]
[Means for Solving the Problem]To achieve the above objectsan invention concerning claim 1The 1st transconductance element which inputs an in-phase component signal of quadrature modulationand defines an output gain of this in-phase component signalThe 1st capacitor for being connected between an output terminal of this 1st transconductance elementand a groundand defining pass band width of an in-phase component signalAn in-phase component output side element which inputs an output of the above-mentioned 1st transconductance elementand defines pass band width of an in-phase component signal with combination with the 1st capacitor of the aboveThe 2nd transconductance element which receives a quadrature component signal of quadrature modulation and defines an output gain of this quadrature component signalThe 2nd capacitor for being connected between an output terminal of this 2nd transconductance elementand a groundand defining pass band width of a quadrature component signalA quadrature component output side element which inputs an output of the above-mentioned 2nd transconductance elementand defines pass band width of a quadrature component signal with combination with the 2nd capacitor of the aboveAn element for frequency shifts for being connected between a node of the above-mentioned 1st transconductance element and an in-phase component output side elementthe above-mentioned 2nd transconductance elementand a node of a quadrature component output sideand shifting center frequency of a pass bandIn a preparation ****** band pass filterit is connected between an output terminal of the above-mentioned 1st transconductance elementand a groundThe 1st resistance generating element which generates resistance for negating distortion of a pass band of an in-phase component signal generated with the limited frequency characteristic of this 1st transconductance element and the above-mentioned element for frequency shiftsIt is connected between an output terminal of the above-mentioned 2nd transconductance elementand a groundThe 2nd resistance generating element which generates resistance for negating distortion of a pass band of a quadrature component signal generated with the limited frequency characteristic of this 2nd transconductance element and the above-mentioned element for frequency shifts was provided.
[0016]An invention concerning claim 2 used a resistance element as the above 1st and 2nd resistance generating element. An invention concerning claim 3 used a transistor element which operates in a triode field as the above 1st and 2nd resistance generating element. An invention concerning claim 4 determines resistance of the above-mentioned 1st resistance generating element with the

limited frequency characteristic of the above-mentioned 1st transconductance element and an element for frequency shiftsand a value of the 1st capacitor of the aboveThe limited frequency characteristic of the above-mentioned 2nd transconductance element and an element for frequency shifts and a value of the 2nd capacitor of the above determine resistance of a resistance generating element of the above 2nd.

[0017]According to the above-mentioned compositionit becomes possiblefor example during the 1st capacitor and a ground to cancel distortion of a signal of a pass band by arranging a resistance element or a transistor element to each between the 2nd capacitor and a ground. And distortion of this signal can be certainly lost by making resistance given by the above-mentioned resistance element or a transistor element into a value shown in above-mentioned claim 4.

[0018]That isdistortion of a pass band of an output signal generated with the limited frequency characteristic (characteristic of a cut off frequency) of a transconductance element and an element for frequency shifts (gyrator element) can be expressed with the transfer function H (s) of the following expression 2.

[0019]

[Equation 2]

$omega_b$ is angular frequency.

[0020]With this expression 2as for Rabove $omega_b$ serves as resistance of the 1st or 2nd resistance generating element with a frequency characteristic [that a transconductance element and the element for frequency shifts are limited (for examplecut off frequency)]. It will newly generate very much (portion of $s/omega_b$) with the limited frequency characteristic of a transconductance element and the element for frequency shiftsand that pole will bring distortion to a pass band so that the denominator of this expression 2 may show. Thenthe value of $R=2/(omega_b C)$ is inserted in R of a numerator so that this newly generated pole may be negatedand it carries out as [disappear / by this / the excessive pole of a denominator]. Howeverthe transfer function H (s) of this expression 2 is materialized when the frequency characteristic of a transconductance element and the element for frequency shifts is equalThe above-mentioned angular-frequency $omega_b$ is a value which becomes settled in both angular-frequency $omega_b 1$ of a transconductance elementand angular-frequency $omega_b 2$ of the element for frequency shifts.

[0021]

[Embodiment of the Invention]The composition of the complex band pass filter concerning the 1st example of this invention is shown in drawing 1and this filterLike the case of drawing 4have a transconductance of gm3a and it has a transconductance of the 1OTA(operational research transconductance amplifier) 21 which inputs input signal X_R of the in-phase component of quadrature modulationand gm1aIt has a transconductance of the 3OTA23 which is arranged in the latter part of above-mentioned 1st OTA21and outputs output signal Y_R of an

in-phase componentand gm3bIt has a transconductance of the 2OTA22 which inputs input signal X_I of the quadrature component of quadrature modulationand gm1band the 4th OTA24 which is arranged in the latter part of above-mentioned 2nd OTA22and outputs output signal Y_I of a quadrature component is provided.
[0022]In order to achieve a frequency shift functionbetween the nodes B of the above-mentioned 1st OTA21the node A of 3rd OTA23 and the above-mentioned 2nd OTA22and 4th OTA246th OTA26 (gyrator element) with the transconductance of the 5OTA25 and gm2b with the transconductance of gm2a is provided. Between the above-mentioned node A and a groundthe 1st capacitor 27 of capacity Ca is connected and the 2nd capacitor 28 of the capacity Cb is connected between the above-mentioned node B and a ground.
[0023]And between the 1st capacitor 27 of the aboveand a groundthe series connection of the 1st resistance 29 of resistance Ra is carried outand the series connection of the 2nd resistance 30 of the resistance Rb is carried out between the 2nd capacitor 28 of the aboveand a ground. This resistance Ra and Rb can be calculated as follows. The above-mentioned transconductance and capacity are made into gm1a=gm1b=gm1gm2 a=gm2b=gm2gm3a=gm3b=gm3and Ca=Cb=CIf gm makes f_b frequency (cut off frequency) downed -3 dB and makes angular frequency $omega_b$=2pi$f_b$above-mentioned Ra and the value of Rb will be calculated by Ra=Rb=R=2/($omega_b$C).
[0024]The transconductance of 5th OTA25 and transconductance gm2 of 6th OTA26the above-mentioned resistance R mainlyThe transconductance of 1st OTA21 and the frequency characteristic of transconductance gm3 of 2nd OTA22 determineIf angular frequency $omega_b$2 and the above gm of 3-3 dB fall [angular frequency] the angular frequency the above gm of 2-3 dB falls [angular frequency] is set to $omega_b$3It is preferred R<Req and in the case of $omega_b$2>$omega_b$3to set up so that the relation of R>Req may be materialized on the other hand in the case of $omega_b$2<$omega_b$3and they can ensure dissolution of distortion by this. Above Req is the resistance in $omega_b$2=$omega_b$3=$omega_b$and is Req=2/($omega_b$C).
[0025]If signal X_R of an in-phase component is inputted into 1st OTA21 according to the complex band pass filter of the above example [1st]by the gain determined by transconductance gm3a. And if signal Y_R of the pass band width determined by capacity Ca and transconductance gm1a is outputted from the 3OTA23 and input signal X_I of a quadrature component is inputted into 2nd OTA22Signal Y_I of the pass band width which is a gain determined by transconductance gm3band is determined by the capacity Cb and transconductance gm1b is outputted from the 4OTA24. As drawing 5 explainedfrequency is shifted to those for Masakata only the quantity determined with the above-mentioned capacity Ca and Cband transconductance element gm2a and gm2b.
[0026]The frequency characteristic of the 4th Bata Wace type complex band pass filter which carried out cascade connection of the filter of drawing 1 is shown in drawing 2. [when the frequency (cut off frequency) which makes the value of gm of OTA 21-26 and the capacity C of the capacitors 27 and 28 be the same as that

of the case of above-mentioned drawing 6and falls by -3 dB by gm of above-mentioned OTA 21-26 in this example is 20 MHz]It could be $Ra=Rb=R=2/(omega_b C)$ =2/(2pi20x10 ^{6}and 10x10^{-12}) =1592ohm. From this drawing 2it is understood that distortion is lost into the pass band portion (1-MHz field centering on 2 MHz).

[0027]The composition of the complex band pass filter concerning the 2nd example of this invention is shown in drawing 3and a transistor element is used for this 2nd example as a resistance generating element. In drawing 4although the composition of the 1st thru/or 6th OTA 21-26and the 1st and 2nd capacitors 27 and 28 is the same as that of the 1st exampleThe series connection of the 1st transistor 31 that operates in a triode field between the 1st capacitor 27 of the above and a ground is carried outand the series connection of the 2nd same transistor 32 is carried out between the 2nd capacitor 28 of the aboveand a ground.

[0028]And with this 1st transistor 31by changing the gate voltage Varesistance Ra is generated and the resistance Rb is generated by changing the gate voltage Vb with the 2nd transistor 32. As this resistance Ra and Rbthe value obtained by $2/(omega_b C)$ as mentioned above is set up. According to such 2nd examplethe resistance Ra and Rb can be changed with the 1st transistor 31 and the 2nd transistor 32and distortion of the signal of a pass band can be canceled good like the case of the 1st example by this.

[0029]

[Effect of the Invention]In [according to / as explained above / this invention] a complex band pass filterThe resistance element or transistor which generates the resistance for negating distortion of the pass band of an in-phase component signal between the output terminal of the 1st transconductance element and a ground is arrangedSince the resistance element or transistor which generates the resistance for negating distortion of the pass band of a quadrature component signal between the output terminal of the 2nd transconductance element and a ground has been arrangedIt becomes possible to obtain a high order complex band pass filter with a good frequency characteristicwithout being able to improve distortion of the signal of the filter pass band region resulting from the frequency characteristic of operational research transconductance amplifier goodand enlarging circuit structure.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1]It is a circuit diagram showing the composition of the complex band pass filter concerning the 1st example of this invention.

[Drawing 2]It is a figure showing the frequency characteristic of the 4th complex band pass filter of an example (only positive frequency is shown).

[Drawing 3]It is a circuit diagram showing the composition of the complex band

pass filter concerning the 2nd example.

[Drawing 4]It is a circuit diagram showing the composition of the conventional complex band pass filter.

[Drawing 5]It is an explanatory view showing the frequency shift in a complex band pass filter.

[Drawing 6]It is a figure showing the composition of the 4th Bata Wace type complex band pass filter which carried out cascade connection of the complex band pass filter.

[Drawing 7]It is a figure showing the ideal frequency characteristic in the complex band pass filter of drawing 6.

[Drawing 8]It is a figure showing distortion of the signal produced with the complex band pass filter of drawing 6 (only positive frequency is shown).

[Description of Notations]

121 -- The 1st OTA (operational research transconductance amplifier)
222 -- The 2nd OTA323 -- The 3rd OTA
424 -- The 4th OTA525 -- The 5th OTA
626 -- The 6th OTA
727 -- The 1st capacitor
828 -- The 2nd capacitor
29 -- The 1st resistance and 30 -- The 2nd resistance
31 -- The 1st transistor
32 -- The 2nd transistor.